

TWO LATE *MONOGRAPTUS* SPECIES FROM VICTORIA, AUSTRALIA,
AND THEIR SIGNIFICANCE FOR DATING THE
BARAGWANATHIA FLORA

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Abstract

The graptolites associated with *Baragwanathia* in the most widespread development of plant-graptolite beds, i.e. the Wilson's Creek Shale and its equivalents, long regarded as varieties of the Lower Ludlow *Monograptus uncinatus*, are shown to belong to a new species *M. thomasi* herein described and compared with similar species, particularly *M. praehercynicus* Jaeger. *M. thomasi* characterizes the highest graptolite zone known from Australia. *Monograptus acquabilis* (Přibyl), an index species of the basal Lochkovian ($\epsilon\gamma$) (= Lower Gedinnian) *M. uniformis* zone, is described from plant-graptolite beds containing abundant *Baragwanathia* 1,500 ft stratigraphically below the horizon of *M. thomasi*. The occurrence of tentaculitids indicating approximate equivalents of the zone of *M. hercynicus* (late Lochkovian) 3,500 ft above the zone of *M. thomasi* suggests that the zone of *M. thomasi* is of probable Middle Lochkovian age, though a younger age may be possible from the morphology of the graptolite.

The *Baragwanathia* flora accordingly makes its first appearance in post-Ludlow times, the earliest adequately dated occurrence being of basal Lochkovian (Lower Gedinnian) age. Its earliest appearance, therefore, is approximately coeval with the earliest undoubted vascular plants in Europe.

Introduction

The association of plants and graptolites has been familiar to Victorian geologists since the beginning of this century. It was noted by such pioneers as W. Baragwanath, F. Chapman, H. Herman, E. W. Skeats, and O. A. L. Whitelaw, and later by Wm J. Harris, R. A. Keble, D. E. Thomas, and others (cf. Lang & Cookson 1935, p. 422-425; Harris & Thomas 1937, p. 69; 1941). It was not until the work of W. H. Lang & I. C. Cookson that this association achieved world-wide fame, the flora being regarded as 'the most ancient vascular land plants yet known from any part of the world' (Lang & Cookson 1935, p. 422). The most frequent and characteristic plant of this early vascular flora is *Baragwanathia longifolia* Lang & Cookson which possesses a stout stem clothed with spirally arranged, long simple leaves; it is generally regarded as a lycopod (e.g. Banks 1960, p. 60).

The *Baragwanathia* flora has for many years been generally regarded as Silurian because of the associated graptolites; correlation varied from earlier determinations of early Wenlock and late Llandovery (Tarannon) to Lower Ludlow. The latter correlation was accepted for more than two decades following Elles's (in Lang & Cookson 1935) identification of graptolites from two important *Baragwanathia* localities as chiefly varieties of *Monograptus uncinatus* Tullberg. This determination was adopted by Harris & Thomas (1937 and later work) 'though not without hesitation' (H. & Th. 1937, p. 69). A part of the plant-graptolite association, which at that time had not yielded identifiable plants, was assigned to the basal Wenlock by Harris & Thomas (1937, p. 69) who believed *M. vomerinus* (Nicholson) and its variety *crenulatus* Törnquist to be present. For

a full appreciation of Elles's and Harris & Thomas's identifications, one must bear in mind that, until recently, there was a relative lacuna in knowledge of the species-groups with which they were comparing the Australian forms.

Photographs in Lang & Cookson (1935) demonstrating the association of graptolites and *Baragwanathia* on the same bedding plane, and the figures and descriptions given by Harris & Thomas (1937) led Jaeger (1959, p. 84-5) to suspect that the graptolites, hitherto identified as varieties of *M. uncinatus*, were younger forms belonging to the *M. hercynicus* group and were accordingly suggestive of an Upper Ludlow (Lochkovian, $e\gamma$), Gedinnian, or even younger age. Tenuous evidence from their widespread occurrence in abundance to the exclusion of other graptolite species lent some support to this conclusion, for *M. uncinatus* and *M. micropoma* are comparatively rare in the European Ludlow, being much overshadowed by other and more common species of *Monograptus*. Subsequent inspection of graptolites associated with *Baragwanathia* housed in European museums reinforced my suspicion that close relationship to a known Lower Ludlow or older graptolite species could be ruled out. Owing to the scantiness of the material available, I could not prove specific identity with the generalized German form *M. praehercynicus* Jaeger and accordingly indicated their similarity to that species by labelling them *M. cf. praehercynicus* (Jaeger 1962a, p. 131; 1962b).

In the meantime, G. Solle (1959) had very cautiously advanced the hypothesis that the association of the presumed Lower Ludlow graptolites with *Baragwanathia* could be due to reworking of the *Monograptus* rhabdosomes from older rocks during early Devonian times. The wide distribution and abundance of the plant-graptolite associations shows this suggestion to be untenable.

My notes on the age of the *Baragwanathia* flora and the accompanying graptolites have received wide notice. Mention need be made however only of articles by W. B. N. Berry (1964a & b) and G. M. Philip (1964), in which unpublished and preliminary data of mine play an important role. Berry was primarily concerned with graptolites from the *Baragwanathia*-bearing beds at Eildon. In his first paper he recorded two forms said to resemble *M. praehercynicus* and *M. microdon*; in the second paper they were described as '*Monograptus* sp. nov. (of the *M. hercynicus* type) formae A and B', leaving it undecided whether the two represent true species or are merely preservational forms. Largely on the basis of those graptolites, Berry assigned the *Baragwanathia*-bearing strata at Eildon and at the 19 Mile Quarry (Yarra Track) to the Gedinnian. Berry's correlation has been challenged by Philip (1964), partly on evidence derived from shelly fossils and partly on the basis of a working hypothesis advanced by me (in litt.). According to Philip, 'it seems likely that all of the upper graptolite occurrences are of the same age, viz. pre-Gedinnian and probably late Ludlovian'.

Amplification of my provisional view seems desirable in view of its publication by Philip. After receiving the first samples of a representative graptolite collection from the Geological Survey of Victoria, I became for a short while less certain as to its stratigraphic position than I had been previously, and was inclined to assume a possible age for the *Baragwanathia*-graptolite beds somewhere in the interval between the $e\beta_1/e\beta_2$ boundary on the one hand and the top of the Lochkovian ($e\gamma$) on the other, or even to suggest an age around the $e\beta_1/c\beta_2$ boundary. At this latter horizon, several still undescribed graptolite species belonging to various lineages are characterized by a distinct stretching of the proximal parts of their rhabdosomes in a way reminiscent of the proximal elongation typical of *M. thomasi* n.sp. However, other evidence indicates a younger age for the *Baragwanathia* flora in close agreement with my original opinion.

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Stratigraphic implications, including the age of the *Baragwanathia* floras

The work of various authors, particularly Alberti (1962, 1963), Boucot (1960), Boucot & Pankivskyj (1962), Hollard (1963, 1965), Jaeger (1962, and review 1965), and Walliser (1962, 1964) regarding the range of brachiopods, trilobites, graptolites, *Scyphocrinus*, and conodonts shows that the base of the Gedinnian sensu Richter & Richter (1954) corresponds to the base of the Lochkov stage ($e\gamma$) in the graptolitic facies. In order to have a precise and widely applicable lower limit for the Lochkovian ($e\gamma$), I take the first appearance of *Monograptus uniformis* Přibyl as indicating the beginning of this stage. This event coincides approximately with, for instance, the entrance of the conodont *Icriodus woschmidti* Ziegler, the trilobite *Warburgella rugulosa* (Alth), and slightly overlaps with the highest occurrence of the crinoid *Scyphocrinus elegans* Zenker. All these fossils are widely distributed over much of Europe and North Africa; some are known also from North America.

Now *M. aequabilis* is a key fossil for the basal Lochkovian *Monograptus uniformis* zone (cf. description later). Its occurrence, therefore, within equivalents of the Eildon Beds at the 20 Mile Quarry, Yarra Track, in Victoria constitutes an important stratigraphic reference point, provided that *M. aequabilis* is here confined to the same horizons as in Europe. This reservation should be stressed, because the phylogeny of *M. aequabilis* is not known and its Victorian occurrence is to some extent out of succession. At the 20 Mile Quarry, *M. aequabilis* occurs with the oldest adequately dateable vascular plants, including *Baragwanathia*, known from Victoria (Cookson 1945). This horizon is not known with certainty elsewhere.

Another plant-graptolite association characterized by *Monograptus thomasi* n.sp. and a variety of plants including *Baragwanathia* and *Hedeia* is widely distributed over central Victoria. At the 19 Mile Quarry on the Yarra Track it occurs approximately 1,500 ft stratigraphically above the zone of *M. aequabilis*. Despite this wide distribution we are presently unable to precisely correlate occurrences of vascular plants elsewhere in Victoria stratigraphically beneath the zone of *M. thomasi*. It is possible that some of these are older than the zone of *M. aequabilis* because great thicknesses of sediment are involved, e.g. in the Yea-Molesworth district (Couper 1965). In the Seymour district, *M. thomasi* occurs through an appreciable stratigraphic thickness at the top of many thousands of feet of plant-bearing sediments (Schleiger 1964, Fig. 14 and pers. comm.).

On the other hand, it is important to note that though suggestive 'chaff' has been found associated with Lower Ludlow (*nilssoni* zone) graptolites in the Heathcote district, no definite vascular plant remains have yet been found in areas where this horizon is known with certainty, viz. in west-central Victoria between Melbourne and Heathcote (Talent, pers. comm.). Though long known from the Melbourne area (Jones 1927), the zone of *M. nilssoni* is best documented for Victoria, as far as stratigraphy is concerned, in the Heathcote-Redcastle district (Harris & Thomas 1937; Thomas 1940, 1941). Graptolites from the Dargile Formation, Parish of Redcastle, Locality 43 of Dr Thomas, have been identified (Harris & Thomas 1937) as *M. bohemicus* and *M. colonus*, with which determinations I agree. A rhabdosome from the parish of Heathcote, locality 35, about 500 ft stratigraphically lower than loc. 43 (Talent in litt.) has been determined (Harris & Thomas 1937, Pl. II, fig. 29) as *M. uncinatus* var. *orbatus*. Better preserved specimens, collected later from the same locality, closely approach the Lower Ludlow *M. uncinatus* s.s. but are distinct, perhaps a new species or subspecies; scarcity of material precludes adequate description.

It remains, therefore, to discuss the age of *M. thomasi*, for though it is closest to *M. praehercynicus* Jaeger, the Middle Lochkovian zone fossil in Thuringia and Bohemia, no precise date can be inferred from its morphology. The *M. thomasi* horizon occurs between the *M. aequabilis* horizon and the long-known *Panenka-tentaculite* association found widespread in the Tanjil Formation some 3,500 ft stratigraphically above the *M. thomasi* zone. This fauna contains (Talent 1965) the oldest small tentaculite species *Nowakia intermedia?* (Barrande), *Novakia acuaria* (Richter), and others which, from Central Europe to North Africa, do not appear before the *M. hercynicus* zone, indeed coming in some distance above the base of the *hercynicus* zone. The cited tentaculites can be regarded accordingly as heralding the late Lochkovian *hercynicus* zone in Victoria; this assumption is consistent with other fossil evidence (Talent 1965).

Some adjustment of relative ranges of tentaculitids and monograptids may result from more detailed work. Graptolitic slate samples from the Road River Formation, Richardson Mountains, Yukon, Canada, sent to me by Dr D. E. Jackson contain *M. cf. praehercynicus* associated with *N. cf. acuaria* (identification confirmed by Dr K. Zagora). Though *M. hercynicus* has not been recorded from this formation, the ranges of *M. praehercynicus* and *M. hercynicus* overlap notably in Thuringia. Nevertheless, the Yukon association could indicate that the first occurrence of these small tentaculites is before the zone of *M. hercynicus* in distant parts of the world.

The top of the Lochkovian is currently equated with an undefined level somewhere within the Siegenian, possibly very high in the Siegenian. It is not known how the Lochkovian graptolite zones are distributed between the Gedinnian and Siegenian. It is certain, however, that the *uniformis* zone starts at the base of the

Gedinnian at least. Hence, the oldest possible correlation for the *Baragwanathia-M. thomasi* association would be extending through the late Lower Gedinnian; it may well range into the Upper Gedinnian; even an early Siegenian age cannot be ruled out.

Baragwanathia itself ranges still higher to the top of the Tanjil Formation, roughly corresponding to the boundary between the Lochkovian and Praguian. The maximum range in age of *Baragwanathia* is accordingly early Gedinnian to latest Siegenian. *Baragwanathia* and its associates, therefore, are not older than the European vascular plants from the Downtonian to Breconian, and the Gedinnian to Lower Emsian of, for instance, the British Isles, Germany, and Spitzbergen.

The correlation scheme which emerges from this partial graptolitic and tentaculitic sequence is summarized in Table 1.

TABLE 1

Correlation of the late Silurian-early Devonian sequence of central Victoria with the Bohemian and British-Rhenish standard successions (dotted lines indicate uncertain boundaries)

| | | | | |
|----------------------------|--------------------------|--|---|----------------------------------|
| | Walhalla Group | | Praguian (f) | Emsian |
| | Tanjil Formation | <i>N. acuaria</i> <i>N. intermedia?</i> | <i>M. hercynicus</i> | Siegenian |
| McIvor & Mt Ida Formations | Wilson's Ck Shale | <i>M. thomasi</i> | Lochkovian (e γ) <i>M. praehercynicus</i> <i>M. uniformis</i> | Gedinnian |
| | Eildon Beds (upper part) | <i>M. aequabilis</i> | | |
| Dargile Formation | | in unit 2: <i>M. sp. aff. uncinatus</i> , <i>M. bohemicus</i> | Budnianian (e β_1 + e β_2) | Downtonian (partim) Ludlovian |

Notes on the age of some European plant-graptolite associations

As a background to correlation of the early Devonian vascular floras of Australia, I have been asked by palaeobotanists to comment on the age of the European plant-graptolite occurrences. The questionable *Cooksonia* specimens described and listed by Obrhel (1962a, 1962b) from the type Lochkovian (e γ) in Bohemia are of the same age as the earliest *Baragwanathia* in Victoria or slightly younger. Specimens from the basal Upper Budnianian (e β_2) *Monograptus ultimus* zone in Bohemia, also assigned by Obrhel to *Cooksonia* (partly with certainty and partly doubtfully) are definitely of pre-Gedinnian age. I am undecided whether the *ultimus* zone falls within the latest Upper Ludlovian or into the Downtonian. Recent work of Walliser (in litt.) on conodonts suggests that a great deal of the e β_2 stage, namely the portion up to the base of the *Monograptus transgrediens* zone, might still be Upper Ludlovian. Hence, the *ultimus*-zone plants would be late Upper Ludlovian rather than Downtonian.

The 'Taeniocrada-like fossil' of W. Zimmermann (1953, p. 176, Abb. 3) from the locality Wiedaer Hütte, Harz Mountains, Germany, originally assigned to the

Lower Ludlovian and repeatedly used by Zimmermann for the construction of phylogenetic trees, is associated with *Monograptus transgrediens* Perner, and hence is of late $e\beta_2$ age, i.e. Downtonian or (less probably) uppermost Upper Ludlovian.

The possible land plant *Saxonia microphylla* Roselt (1962), from the Vogtland, Germany, to which the unspecified label 'Ludlovian' was originally attached, is associated with *M. transgrediens*?, *M. cf. uniformis*, and others; has definitely come from the German Upper Graptolitic Slates. It is, therefore, of late $e\beta_2$ or, more probably, of early $e\gamma$ age, i.e. either uppermost Upper Ludlovian to Downtonian or, more likely, Lower Gedinnian.

Psilophyton? hedei Halle (1920) in the Hemse Marl at Hablingbo, island of Gotland, Sweden, occurs on the same slab as *Monograptus chinaera* (Barrande), *Retiolites erraticus* Eisenack and other graptolites, proving this association to be Lower Ludlow. Most paleontologists however regard *P.? hedei* as algal rather than vascular.

Monograptus aequabilis (Přibyl 1941)

(Pl. 41, fig. 1-2; Fig. 1d)

1937 *Monograptus vomerinus* (Nicholson), and var. *crenulatus* (Törnquist). Harris & Thomas, *Vict. Grapt.* (n.s.), IV, p. 72, Pl. 1, fig. 14-21. Partly refigured in Thomas 1960, Pl. 13, fig. 176, 178.

1959 *Monograptus aequabilis* (Přibyl). Jaeger, *Grapt. Strat. jüngst. Thür. Sil.* p. 102-105, Fig. 17a-b; Pl. 1, fig. 8; Pl. 4, fig. 3; Pl. 5, fig. 1-5.

MATERIAL: A dozen juvenile and incomplete adult rhabdosomes, entombed in strongly weathered, bleached argillaceous slates. With the exception of a few specimens, which are partly preserved in low relief as brown iron oxide internal casts (steinkerns), the graptolites are compressed, and composed of a very incomplete carbonaceous film. Moreover, all material is deformed by flow cleavage marked on the bedding planes as a fine, but distinct lineation.

DESCRIPTION:

Morphology of rhabdosome and thecae: Rhabdosome small to medium sized, straight, but with slight ventral curvature of the dorsal side in the proximal portion. The specific feature is the peculiar biformism of thecae: th_1 has a large well-developed hook or hood (haube) of the *uncinatus* type, i.e. an unpaired arched mesial shield, which extends from the dorsal side of the virtual thecal aperture down beyond its ventral margin, thus surrounding and enclosing the true aperture completely and producing a new one.

The hood of th_1 is well seen in all available Victorian rhabdosomes with the proximal end preserved. However, owing to the mode of preservation the specimens generally exhibit only a longitudinal section of the hood, which may therefore simulate a spine. Th_2 has a much smaller hood, if at all; this attains at the most $\frac{1}{3}$ - $\frac{1}{2}$ the size of that in th_1 , and just covers the thecal aperture. All succeeding thecae fail to develop a real hood, but instead, after a short transitional interval comprising about th_{3-4} (5), form only well-marked supra-apertural ridges, which project about 0.1 mm over the free ventral walls.

Viewed from the side, the apertures of the thecae give the appearance of small, rounded to triangular excavations. However, orientation, size and outline of the apertures depend strongly on their position relative to the direction of cleavage (lineation) which tends to align the originally horizontal ventral and dorsal margins of the apertures parallel to the lineation.

The apertural margins of the thecae are thickened, and consequently form distinct lips ventrally and laterally. The free ventral walls stand vertical, i.e.

parallel to the axis of the rhabdosome, if seen in side view. Where the free ventral walls are inclined to the axis of the rhabdosome, the inclination appears always to have been caused by oblique embedding of the specimen or post-mortem deformation.

It still remains an open question, whether the described hood-less climacograptid type of thecae persist to the distal end of adult rhabdosomes, or whether they are gradually replaced distally by a simpler form. In the Victorian specimens the climacograptid type of thecae occurs throughout, but the longest rhabdosome has only 25 thecae preserved.

Among the European material there are specimens 60 mm long and consisting of 50 thecae. In these rhabdosomes the distal thecae seem to be simpler, their free ventral walls being inclined, and the supra-apertural ridges appear to be absent. However, all these long rhabdosomes are more or less tilted distally. Since a clear 'false' distalward simplification of the thecae, which evidently has been caused by tilting, can be observed also in rather juvenile rhabdosomes from Europe and Canada, I would now doubt the occurrence of any appreciable, true simplification that goes beyond the climacograptid type of thecae. In any case, the Victorian rhabdosomes and recently discovered Canadian specimens now under investigation, as well as additional material from Bohemia and Germany, prove that at least the proximal 25-30 thecae in *M. aequabilis* are of the climacograptid type. This is a noteworthy supplement to earlier descriptions of this species.

Intertheical septa: In contrast to almost all specimens of *M. aequabilis* known to me from outside Australia, most Victorian rhabdosomes of this species clearly exhibit the intertheical septa. These make an angle of 30°-40° with the rhabdosome axis; only in the proximal 3 to 4 thecae where the septa are very short is the angle of inclination considerably greater—50° or more. These measurements apply to rhabdosomes forming an angle of about 45° with the lineation; specimens lying perpendicular to the lineation exhibit a greater angle of inclination, those lying parallel to it a smaller one.

The septa of the distal and median thecae from about th_7 onward originate approximately at the level of the supra-apertural ridge of each preceding theca, whereas the septa of the proximal thecae take their origin a decreasing distance above the earlier theca until the final stage is reached. Hence, any cross-section through the rhabdosome will nowhere cut more than one intertheical septum; accordingly no overlap of septa occurs.

The length of the nearly straight median portion of the intertheical septa, i.e. the distance from the up-bent proximal portion to the lateral margin of the thecal aperture attains about 0.8 mm in the distal region of the rhabdosome, whereas at th_4 it is not more than 0.4 mm. These measurements can be regarded as original, as they apply to rhabdosomes lying at 40°-50° to the lineation. The respective figures in specimens disposed parallel to the lineation and therefore stretched are 1.2 mm or more, and c. 0.7 mm.

Sicula: The sicula has the usual conc-shape and is directed ventrally; its length could not be measured exactly, but is somewhere between 1.5 and 2 mm; in rhabdosomes parallel to the lineation it has been elongated to more than 2 mm. The width of the (flattened) aperture is 0.35-0.4 mm; in a specimen lying almost normal to the lineation the aperture has been widened to 0.6-0.7 mm.

The dorsal tongue is rather long (0.35-0.4 mm) and strikingly incurved as is the case in *M. uniformis* Přibyl and *M. thomasi* n.sp. This character has also been observed, although rarely, in Thuringian specimens. However, the state of preservation of most Thuringian rhabdosomes and all Bohemian specimens investigated by the writer does not allow precise comparison of this delicate structure.

Dimensions of rhabdosomes (Table 2):

- (i) Number of thecae in the initial cm: 9-10, in the second and third cm about 8. These figures hold only for rhabdosomes forming an angle of 40°-50° with the lineation, i.e. for specimens that have not been tectonically elongated or shortened, and accordingly, may be assumed to have kept the original thecal count. These measurements compare closely with those found to be normal in European and Canadian rhabdosomes. The only two Victorian rhabdosomes lying nearly parallel to the lineation have in the initial cm, 8 thecae, and in the second cm, 6½ thecae (the latter portion being preserved only in one of the two specimens). The only Victorian specimen which is disposed almost normal to the lineation (actually at 75° to it) has slightly more than 12 thecae in the first cm. To summarize, the thecal count in the first cm of the available Victorian rhabdosomes varies between 8 and 12; however, this variability was clearly caused by schistosity, the mean of 10 thecae representing the normal figure.

TABLE 2

Measurements of some *M. aequabilis* rhabdosomes from the 20 Mile Quarry locality, Yarra Track, Victoria

| No. | β | L | width | | thecae/cm |
|-----|---------|----|-----------------|------------|------------|
| | | | th ₁ | distally | |
| 1 | 0-10° | 25 | 0.8 (0.6) — | (1.2-1.3)* | 8; 6½ |
| 2 | 0-10° | 15 | 0.85 (0.6) — | (1.2-1.3)* | 8 |
| 3 | 35-40° | 17 | 0.9 (0.7) — | ? | 9+ |
| 4 | 40-50° | 32 | 0.85 (0.65) — | (1.8-1.9) | 10; 8+; 8+ |
| 5 | 40-50° | 9 | 0.85 (0.6) — | ? | 10 |
| 6 | 40° | 25 | ? | (1.6-1.8) | ?; 8; 8 |
| 7 | 75° | 9 | 1.3 (0.9) — | ? | 12+ |

β = angle between the rhabdosomes and the lineation (= direction of stretching) on the bedding plane. L = length of the rhabdosomes in mm; all specimens are distally incomplete. The first figure giving the width (in mm) refers to th₁ inclusive of its hood; the second (bracketed) figure applies to the width just above the hood of the th₁. Thecae/cm = number of thecae in each succeeding cm starting with the initial cm of the rhabdosome. * = tilted rhabdosomes, the measurements of the width in these cases are too low.

- (ii) Width of the rhabdosome: 0.8-0.9 mm at th₁ including its hood, 0.6-0.7 mm above its hood. These measurements apply both to rhabdosomes nearly parallel to the lineation and those lying at angles of up to 50° with it. In the single measurable rhabdosome lying almost normal to the lineation th₁ is 1.3 mm wide, including the hood and 0.9 mm wide above the hood. In the distal portion of the only well preserved adult specimen, which forms an angle of 40°-50° with the lineation (Pl. 41, fig. 1), the width amounts to 1.7-1.9 mm; this figure is attained between th₁₀₋₁₅, and may be regarded as normal for flattened, but tectonically undisturbed, rhabdosomes. Specimens lying nearly parallel to the lineation are 1.2-1.3 mm wide in their distal part, but as these graptolites are tilted, their true, though tectonically reduced, width may be somewhere between the latter figure and 1.8 mm. No rhabdosomes lying normal to the lineation have their distal parts preserved, but their width may be calculated to be 2.5 mm.

COMPARISON: In the present state of knowledge *Monograptus aequabilis* should be hardly confused with any other graptolite. Harris & Thomas's (1937) assignment of the deformed Victorian specimens to the *Monograptus vomerinus* group was done long before *M. aequabilis* and practically all other post-*leintwardinensis* graptolites, as well as the correlation problems involved, were known. Hence this earlier determination is entirely understandable. The restriction of a full grown hood to the first theca and its early astogenetical development is unique among comparable monograptids. Only *Monograptus micropoma nannopoma* Jaeger (1959, p. 122 ff.) from the European Lower Ludlovian bears some distant resemblance in its shape and size of the rhabdosome and the general character of the thecae. These, however, develop only tiny hoods, which are merely supra-apertural ridges, and occur throughout the rhabdosome; furthermore, they grow only in a very late stage of the astogeny. Larger hoods may occur in the proximal thecae of adult rhabdosomes in the late Valentian/Wenlockian *Monograptus vomerinus* group. However, in these the hoods are neither so conspicuous nor confined to th_1 (2), and the general appearance of the rhabdosome is very different, being always distinctly recurved and pointed proximally and attaining the final width rather slowly. Moreover, all comparable *vomerinus* group rhabdosomes reach far greater lengths (20-30 cm and more). *M. vomerinus crenulatus* Törnquist, to which a number of the Victorian rhabdosomes were provisionally assigned is closer to it than other known *vomerinus* forms, but, in addition to differences listed above, it is distinguished by the greater number of thecae in the proximal cm, namely 12-13, against 9-10 in *M. aequabilis*.

AUSTRALIAN OCCURRENCE: 20 Mile Quarry, Yarra Track, Victoria (Harris & Thomas 1947, p. 45-48, Fig. 3). Three small rock specimens were available in which rhabdosomes of *M. aequabilis* occur scattered, but frequently, and to the exclusion of any other graptolite species. From Harris & Thomas's (1937, p. 72) observations it can be also concluded that *M. aequabilis* occurs without other associated graptolites. This mode of occurrence is reminiscent of that in Thuringia and Canada where *M. aequabilis* generally crowds bedding planes without being associated with any other graptolite species. In Victoria *M. aequabilis* occurs in the Eildon Beds in more argillaceous lateral equivalents of the upper half of the predominantly sandy McIvor formation of the Heathcote district to the NW. (Talent 1965).

AGE: *M. aequabilis* has been recorded from the basal Lochkovian ($e\gamma$) zone of *Monograptus uniformis* in Central Bohemia (Czechoslovakia), Thuringia (Germany), and Bulgaria. In the Thuringian Upper Graptolitic Slates, where *M. aequabilis* occurs frequently and where its vertical range could be most precisely determined, it is demonstrably confined to the lower and especially the middle part of the *uniformis* zone. *M. aequabilis* has recently been recognized by the writer in the Petit Portage member of the Cape Bon Ami formation, Gaspé Peninsula, Quebec, Canada (specimens collected by Dr L. M. Cumming of the Canadian Geological Survey). In Gaspé, *M. aequabilis* is not associated with other graptolites, but evidence from other fossils seems consistent with the view that it occurs there at the same stratigraphical level as in Europe (Boucot, Cumming, & Jaeger 1965).

Since there seems to be no evidence to the contrary, the Australian occurrence of *M. aequabilis* may also be regarded as of basal Lochkovian age, and accordingly correlated with the basal Gedinnian. The discovery of *M. aequabilis* in Victoria emphasizes its significance as a guide fossil, and indicates its world-wide distribution (however, cf. reference earlier under 'Stratigraphical Implications').

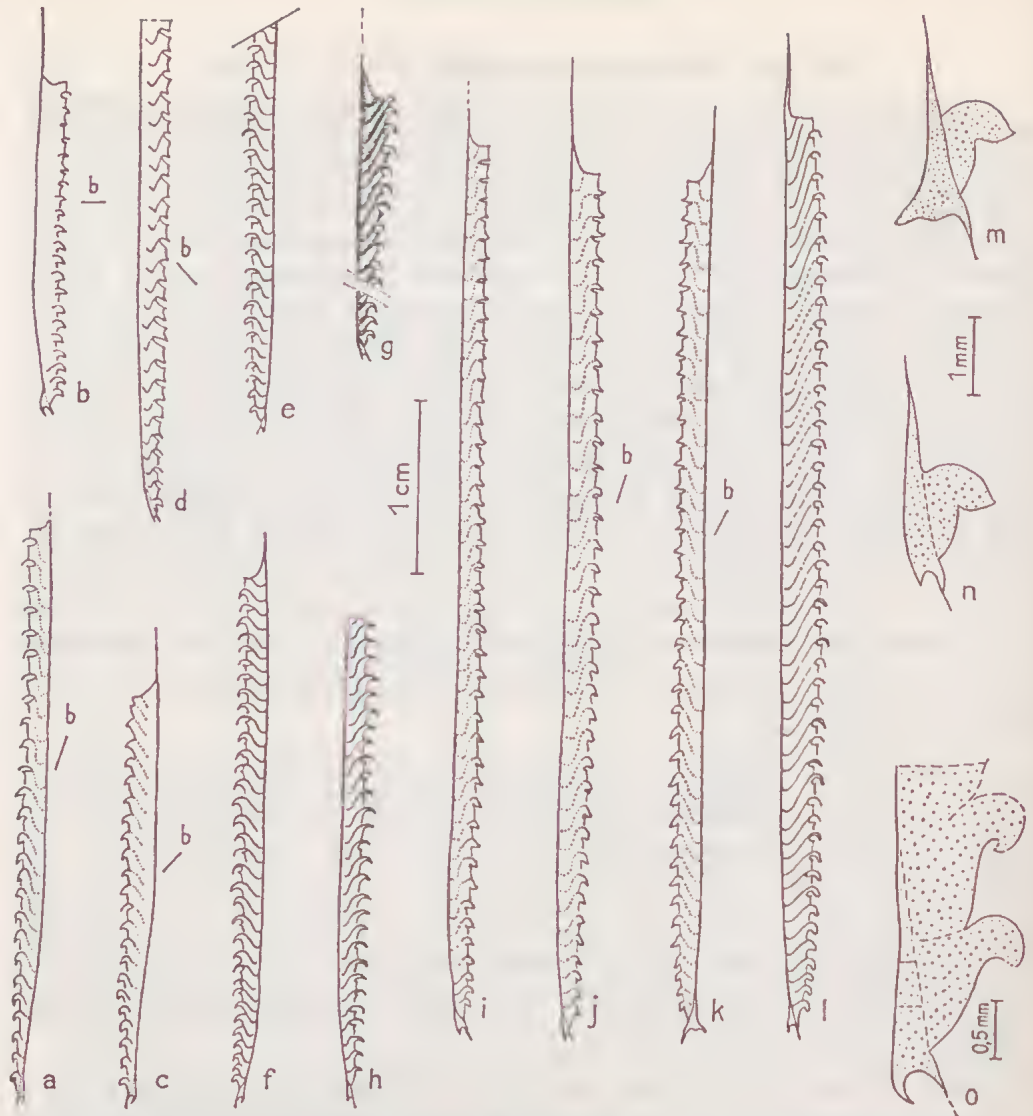


FIG. 1—Sketches of several uncinatid *Monograptus* species, demonstrating specific features. All have been drawn individually, but slightly schematized. Broken lines, particularly for intertheal septa, are conjectural, i.e. not observed in the rhabdosome forming the basis for the sketch. All rhabdosomes are more or less flattened, except 1 g, which is preserved in full relief; in addition, several specimens have been deformed by cleavage, the direction of stretching being indicated by a stroke (letter b). For further explanations see text.

- a-c — *M. thomasi* n.sp., 19 Mile Quarry, Yarra Track, Victoria. (c) = holotype (Pl. 43), (a) + (o) from the same slab (Pl. 42, fig. 7), (b) = Pl. 42, fig. 2.
 d — *M. aequabilis* (Přibyl), 20 mile Quarry, Yarra Track; the specimen from Pl. 41, fig. 1.
 e — *M. cf. praehercynicus* Jaeger, Čertovy schody, Bohemia, low in the zone of *M. uniformis*, Lochkovian. G. 504-1, Mus. Pal. Berlin.
 f — *M. uncinatus* Tullberg, probably Dudley, Welsh Borderland, Lower Ludlow. Dean coll., Univ. Birmingham, B.U. 713.
 g — *M. uniformis* Přibyl, Karlík, Bohemia, close to base of *uniformis* zone, Lochkovian. G. 505-1, Mus. Pal. Berlin.
 h — *M. sp. aff. similis* Přibyl. Boring Leba 1 (767, 60 m) Pomcrania, zone of *M. ultimus*, base of Upper Budnianian ($e\beta_2$). Zentr. Geol. Inst. Berlin.
 i — *M. micropoma* (Jaekel), Gräfenwarth, Thuringia, Lower Ludlow, *scanicus* zone. G. 441 d, Mus. Pal. Berlin.
 j, n — *M. praehercynicus* Jaeger, Ramstal, Thuringia, Lochkovian, *praehercynicus* zone. G. 65a (Holotype), (n) *ibid.* = G. 51 β , Mus. Pal. Berlin.
 k, m — *M. hercynicus* Perner, (k) Ramstal, Thuringia, Lochkovian, *hercynicus* zone. G. 15 β , Mus. Pal. Berlin. (m) Gräfenwarth, Thuringia, G. 410 β , Mus. Pal. Berlin.
 l — *M. uniformis* Přibyl, Lejškov, Bohemia, Lochkovian, *uniformis* zone. G. 337, Mus. Pal. Berlin.

Whether Willefert's (1962) '*Monograptus aequabilis* nov. var.' from a deep bore in the northern Algerian Sahara belongs to this species appears doubtful. According to Willefert, the Algerian specimens differ from the true *M. aequabilis* in being narrower (1.5 mm instead of 2 mm) and having more closely spaced thecae (12-14 proximally instead of 9-10). Furthermore, they occur in a much lower horizon, namely the basal portion of the Pridoli stage ($e\beta_2$), being associated with the characteristic *Monograptus formosus* Bouček. Unfortunately, I feel unable to judge the morphology of the specimens safely from the single photograph given.

REPOSITORY: Mines Department of Victoria, Geological Survey Museum, Melbourne, Victoria, Australia, No. 59523-25.

***Monograptus thomasi* n.sp.**

(Pl. 41, fig. 3-5; Pl. 42, fig. 2-7; Pl. 43, fig. 1a-c, o)

SELECTED SYNONYMY:

- 1906 *Monograptus dubius* Suess. T. S. Hall, Rep. Grapt., p. 267, Fig. 3. Further specimens from other localities in the Jordan River Beds of the Aberfeldy District, cited as *M. cf. dubius*, *M. sp.* and others (p. 268-271), as well as quotations of *M. cf. dubius*, *M. cf. crenulatus*, *M. sp.* (*colonus* group) and others in Hall 1907, p. 140-141, most probably belong also in this synonymy.
- 1925 *M. dubius* Suess etc. Baragwanath, Aberfeldy district, p. 21-22 (only quotations of T. S. Hall's determinations cited above).
- 1933 *Monograptus rickartonensis* Lapworth-Keble, Middle Sil. Land Plants, p. 293, Pl.
- 1935 *Monograptus uncinatus* var. *orbatus* Wood, *M. uncinatus* var. *micropora* (Jaekel) (clerical error—recte: *micropoma*), and *M. chimaera* (Barrande). Elles in Lang & Cookson, Vascular Land Plants . . . *Monograptus* from Victoria, p. 422, Pl. 32, fig. 51-53.
- 1935 *Monograptus cf. galaensis* Lapworth. Thomas in Lang & Cookson ut sup. (Unpublished and preliminary identification by Thomas, cited as *M. galaensis* in L. & C.).
- 1937 *Monograptus uncinatus* var. *orbatus* Wood, and *M. uncinatus* var. *micropoma* (Jaekel). Harris & Thomas, Vict. Grapt. (n.s.), IV, p. 69, 73-74, Pl. 2, fig. 23-25, 27-28, ? 26, ? 30; non 29 (close to the true *M. uncinatus* Tullberg). Partly re-figured in Thomas 1960, Zonal Distr. Austr. Grapt., Pl. 13, fig. 187-188.
- 1964 *Monograptus* sp. nov. (of the *M. hercynicus* type) forma A and B. Berry, *M. hercynicus* Type Monograptids from Eildon, p. 9-13, fig. 1a, b; Pl. 1-2.

DERIVATIO NOMINIS: In honour of Dr D. E. Thomas, the outstanding authority on Australian graptolites.

HOLOTYPE: The rhabdosome indicated on Pl. 43, Reg. No. 58381, Geological Survey of Victoria, Mines Department, Melbourne.

TYPE LOCALITY: 19 Mile Quarry, Warburton-Wood's Point Rd, Yarra Trunk, Victoria (also referred to as quarry situated about 18½ miles E. of 'MeVeigh's', or 'about 17 miles from Wood's Point'. For this locality see Harris & Thomas 1937, p. 69, and 1947, p. 45-49, Fig. 3.

STRATUM TYPICUM: Wilson's Creek Shale, late Lower to Upper Gedinian or Siegenian (Middle Lochkovian).

MATERIAL: About 100 rhabdosomes in various growth stages, buried in originally black, grey, and also greenish banded argillaceous and silty slates, sometimes partly or totally bleached by weathering to a brownish or even white rock. Most of the graptolites are flattened, and composed of an angularly fragmented carbonaceous film, which in the less weathered slates may be covered by a thick layer of colourless, green, or brownish bladed crystals of micaceous habit. This mineral is somewhat reminiscent of the problematical 'gümbelit' so familiar to German graptolite workers; the diverse colours may indicate modifications due to various stages

of weathering. Some graptolites are preserved in low relief as brown iron-oxide internal casts; others form tubes which are partly filled with black carbonaceous substance (at Eildon).

All the material was affected by transverse flow cleavage. The cleavage planes are generally not strongly developed, and indeed are often weakly developed. These lineations are often rather indistinct and may not be perceived by the untrained observer. In a few cases two lineation systems intersecting each other on bedding planes at 30°-50° appear to be present; however, this impression may be fallacious. The graptolites have been stretched in the direction of the lineation. In the renowned 19 Mile Quarry locality, for instance, rhabdosomes lying parallel to the lineation have been stretched by $\frac{1}{10}$ to $\frac{1}{5}$ of the original dimensions. Specimens disposed normal to the lineation at this locality were correspondingly shortened. Changes in the appearance of the rhabdosomes are connected with considerable deformation of the morphology of the thecae, as may be clearly seen from the accompanying photographs. (For a detailed discussion of the effects of one or more cleavage systems on the morphology of graptolites see Jaeger 1959, p. 67-77).

The degree of deformation observed in the graptolites from the 19 Mile Quarry may be regarded as similar to that from some other localities which have yielded *M. thomasi*, while other localities, owing to lack of material, do not allow a quantitative comparison. The available specimens from Alexandra, locality 9, seem to exhibit no notable elongation caused by cleavage.

The amount of deformation, although small, is not to be neglected. It may escape detection, since rhabdosomes which were more or less tilted during burial may appear appreciably thinner than others, making the same angle with the lineation but presenting their exact side view. Careful consideration combined with measurements of the thecal spacing will, no doubt, help to solve apparent contradictions.

A special case is observed in the silty slates from Alexandra, Geological Survey locality 6. Here the cleavage has caused the bedding planes to be deformed into rather rough, undulating, wrinkle-like surfaces. The greatest movement in this deformation occurred in a direction leading out of the bedding planes (direction (a) of petrofabrics), while the displacement parallel to the lineation (b) was less significant. As a result, all rhabdosomes from this locality exhibit a greater number of thecae in 1 cm than they would show in the undeformed state, regardless of their position relative to the lineation. The thecal count in this case depends largely on the magnitude of crenulation shown by the bedding planes.

DIAGNOSIS: Rhabdosome medium-sized, straight, with stretched proximal portion and slightly reclined proximal extremity. Thecae of *uncinatus* type, with hoods decreasing in size from proximal to distal end; first few thecae with tendency towards isolation. Sricula with relatively long (0.3 mm), strongly incurved dorsal tongue. Dimensions for flattened, but tectonically not deformed adult rhabdosomes: Length: 20-50 mm, commonly 20-30 mm. Width: 1 mm at th_1 across its hood, $\frac{1}{2}$ mm just above the hood of th_1 ; maximum width attained at th_{10} (± 2): 1.8-2.0 mm (1.3-1.6 mm without hoods); number of thecae in 1 cm: 9-10, practically constant throughout the rhabdosome.

DESCRIPTION:

Morphology of rhabdosome and thecae: Rhabdosome straight, but with gentle ventral curvature of the dorsal side behind the initial 5 to 10 thecae. At the proximal end, in the range of the sicula, i.e. behind $th_{1(2)}$, the dorsal side of the rhabdosome is distinctly reclined. This reflexion is obviously due to the presence of the sicula,

which appears to be affixed externally, its inner wall usually more or less continuing the general line of the dorsal rhabdosome margin. The ventral side of the rhabdosome, i.e. the front, formed by the tips of the thecal hoods, is a straight line along the total rhabdosome length, neither taking part in the proximal incurving of the dorsal rhabdosome margin nor in the recurving of the proximal end. Deviations from the described rhabdosome shape can be easily attributed to distortions during burial, or more commonly to deformation thereafter. In more strongly cleaved rocks even moderately sickle-shaped or irregularly bent rhabdosomes may have resulted (e.g. at Alexandra, locality 6).

The character of the distal end may be seen from the illustrations, especially Pl. 43. The virgula can be traced 10 mm or more beyond the rhabdosomic extremity.

The thecae are uniform, of *uncinatus* type; the hoods, after an initial increase in size from th_1 to the th_{4-7} , gradually decrease in magnitude from the proximal to the distal portion of the rhabdosome. Hence the thecae appear hooked especially at the proximal end, say up to th_{3-6} , where the hoods attain their greatest length extending down below the level of the ventral and lateral margins of the thecal aperture, thus completely hiding and enveloping them. In the median and distal rhabdosomic portion, namely from th_{6-10} onward (this interval depending on the effects of cleavage rather than on original morphology), the hoods are such short and laterally less arched shield-like structures, that the lateral and ventral margins of the thecal apertures can be seen in side view; even close to the distal rhabdosome end the hoods project a bit in front of the ventral thecal walls. The adult minimum size of the hoods is attained at th_{12-15} , and remains constant until the distal extremity of the rhabdosome. In the usual state of preservation the hoods offer to the observer only a longitudinal section, and may simulate a spine, i.e. a paired structure in contrast to the unpaired hood. This may explain earlier confusion of this species with *M. chimaera*.

Height of the hoods, i.e. the vertical distance from the proximal (lower) to the distal (upper) extremity of the hoods (terms proximal and distal here used relative to the orientation of the rhabdosome): at $th_1 = 0.4-0.5$ mm; at th_{4-7} (maximum height) = $0.55-0.65$ mm; distally $0.25-0.35$. These are mean values, the actual dimensions varying more strongly owing to the effects of cleavage. For instance, the maximum height for hoods of proximal thecae, observed in tectonically elongated specimens, may attain more than 0.8 mm.

The figures for the horizontal projection of the hoods may be calculated from Table 2, where the widths of representative rhabdosomes have been listed.

The apertural margins of the thecae are thickened and consequently form an externally projecting lip surrounding the apertures on the ventral and lateral sides. The free ventral walls stand vertical, except in th_1 , i.e. parallel to the axis of the rhabdosome, if viewed precisely from the side. Inclinations of the free ventral walls have been affected by tilting during burial and subsequent crushing, and/or by cleavage.

The specific feature of *M. thomasi* is the distinct stretching and thinning in the proximal part of the rhabdosome, giving it a somewhat stalked appearance. This elongation affects the first 3-5 thecae, the elongation diminishing distally. Consequently, these are set farther apart from one another than the immediately succeeding thecae. Moreover, the initial thecae show a tendency towards isolation, which is more strongly and most strikingly pronounced in th_1 . The step from the hood of th_1 to that in th_2 may therefore appear especially wide. As a further consequence of the proximal stretching, the number of thecae in the initial cm of the rhabdosome is less than in the succeeding distances.

As a result of schistosy, the proximal 'stalk' may have been elongated and thus exaggerated in rhabdosomes lying parallel to the lineation, whereas in specimens being disposed normal to the lineation, the 'stalk' may have become entirely obliterated (comp. plates and chapter 'comparison').

Structurally, the hoods are both the distal and external extremities of the dorsal thecal walls or, in other words, the outward and direct continuations of the interthecal septa. This can be most clearly seen in very juvenile rhabdosomes, particularly those having only one theca; the latter have the hood practically completed before th_2 begins to grow. In the investigated material there are three such 1-th-rhabdosomes, two of them very complete, from Alexandra, locality 5 (Cat. No. M 32548A). Unfortunately, they are so delicate, that they could not be successfully photographed. (For comparison, sketches of 1-th-rhabdosomes from *M. hercynicus* and *praehercynicus* have been included as Fig. 1 m, n). In longer rhabdosomes the growth of the individual hoods seems to be slightly delayed. But as can be seen, e.g. on Pl. 43 (left rhabdosome with long-projecting virgula), even the second last theca possesses already a rather large, though possibly not yet completed hood. (Since the periderm in the last-formed, still growing portions of every rhabdosome is very thin—all graptolites exhibit secondary thickening of the periderm—the extremity of this hood may have been destroyed.)

These observations indicate that the astogeny of *M. thomasi* agrees well with that in *M. hercynicus*, *M. praehercynicus*, and *M. uniformis* (Jaeger 1959). The hoods of these four species, consequently, are most closely homologous. Although no growth lines could be detected in any rhabdosome of *M. thomasi*, its thecal hoods should, according to these observations, be composed of broad, normal growth bands (fuselli). (They can be seen in some undescribed specimens of *M. hercynicus*, *M. cf. praehercynicus*, and *M. uniformis*, which I have dissolved out of rock.)

Interthecal septa: These can be easily traced in many of the rhabdosomes from the 19 Mile Quarry locality and from Alexandra, while in many others from the same and other localities the interthecal septa are obscure. In th_1 the interthecal septum is shortest, its straight portion attaining a length of hardly $\frac{1}{2}$ mm, and making an angle of about 60° - 70° with the rhabdosome axis. Through the succeeding thecae the septa become progressively more erect and more elongate (cf. Pl. 42, fig. 4) until the adult stage is reached at th_{6-8} , where the length of the septum amounts to 1 mm \pm 0.2; they then make an angle of 30° - 40° with the virgula, the measured variability being largely due to tectonic deformation and tilting of the rhabdosomes during deposition.

Each of the interthecal septa from th_2 to th_{6-7} originates a decreasing distance above the hood of the preceding theca, but the beginning of the septa in all following thecae up to the distal end lies constantly at the level just touching or slightly cutting the apertural hood of the immediately older theca. Hence, a cross-section through the rhabdosome would nowhere hit more than one interthecal septum, accordingly no overlap of septa will be observed.

Sicula: It has the usual cone-shape throughout its length, amounting to 1.6-1.7 mm \pm 0.1 mm. Any notable cylindrical portion, typical of the apertural region in many species of the *uncinatus* group and others, is lacking. The apex extends up half-way between the hoods of th_1 and th_2 . The aperture is concave, 0.35 mm wide (less than 0.3 mm, if tectonically elongated, or up to 0.5 mm if widened). The dorsal tongue is rather long (more or less 0.3 mm), and strikingly inverted. The virgella attains about 0.5 mm in length. One or two thickening rings ('Stillstandsgürtel' of Kraft) have been observed in a number of siculae.

TABLE 3

Measurements of M. thomasi rhabdosomes

Starred examples are tilted distally, resulting in too low values for the adult width.
(For further explanation see Table 2; see also paragraph under 'material')

| No. | β | L | width | | thecae/cm | locality |
|-----|---------|----|-----------------|-----------------------|-----------|----------------------|
| | | | th ₁ | distally | | |
| 1 | 0-10° | 21 | 0.75(0.4) | — (1.3-1.5)(1.0-1.1) | 8; 8 | 19 Mile Quarry |
| 2 | 10-20° | 29 | 0.85(0.4) | — (1.4-1.6)(1.1-1.2) | 8½; 8½; 8 | " |
| 3 | 30-40° | 22 | 1.0(0.5) | — (1.8-1.9)(1.3-1.4) | 9; 9 | " |
| 4 | 45-55° | 24 | 1.0(0.5) | — (1.9-2.1)(1.6) | 9½; 9½ | holotype " |
| 5 | 55-65° | 25 | 1.1(0.65) | — (2.0)(1.5) | 10½; 9 | 19 Mile Quarry |
| 6 | 80-90° | 19 | 1.3(0.8) | — (2.0)(1.5) | 11½ | " |
| 7 | 45° | 22 | 0.9(0.4) | — (1.6-1.7)(1.3-1.4)* | 9½; 9½ | Alexandra, loc. 5 |
| 8 | 0° | 21 | 0.85(0.5) | — (1.6-1.7)(1.3-1.4) | 9; 9 | " loc. 9 |
| 9 | 20-40° | 12 | 0.8(0.4) | — (1.3-1.4)(1.0) | 13 | " loc. 6 |
| 10 | 70-80° | 13 | 0.8(0.5) | — (1.4-1.5)(1.1-1.2) | 13 | " " |
| 11 | 70-80° | 16 | 1.0(0.65) | — (1.4-1.5)(1.1) | 11 | " " |
| 12 | 0-10° | 12 | 0.8(0.4) | — (1.2-1.3)(1.0) | 8 | Mt Sugarloaf, Eildon |
| 13 | 40-45° | 19 | 0.9(0.6) | — (1.7-1.8)(1.2-1.3)* | 10 | " " |
| 14 | 85° | 12 | 1.3(1.0) | — (2.4-2.5)(2.0) | 12½ | " " |

COMPARISON: *M. thomasi* most closely resembles *M. praehercynicus* Jaeger in shape and size of the rhabdosome as well as in the morphology, structure, and development of the thecae. However, it differs from *M. praehercynicus* in (1) the thin, stalk-like habit of the proximal portion of the rhabdosome; (2) the tendency towards isolation of the first 3-5 thecae resulting in an especially strong projection of th₁; (3) the constant number of thecae in 1 cm throughout the rhabdosome, a phenomenon that is unique among species of the *uncinatus* group, showing in this character always a striking difference between the initial cm and all following; (4) the relatively long (0.3 mm), ventrally bent dorsal tongue of the sicula, rendering its aperture rather disproportionate.

M. praehercynicus, on the contrary, lacks the stretching in the proximal rhabdosome portion and all features involved, being rather robust and thick also between the hoods of the proximal thecae. Hence, the rhabdosomes of *M. praehercynicus* appear to be more harmoniously shaped. The width between the hoods of th₁ and th₂ in the flattened, but tectonically undeformed rhabdosomes, amounts to 0.7-0.8 mm or even more, against 0.5 mm in *M. thomasi*. The hoods are less projecting. The number of thecae in the initial cm is $10 \pm \frac{1}{2}$, but only about 8½ in the succeeding stretches. The dorsal tongue of the sicula is slightly shorter (0.2 mm) and less incurved, thus rendering the sicula more graceful.

The differences between *M. thomasi* and *M. praehercynicus* can become largely obliterated by cleavage. If lying on the bedding plane at right angle relative to the direction of stretching, the resulting shortening and widening of the *thomasi* rhabdosome may lead to the complete reduction of the characteristic proximal 'stalk', and instead may produce a distinct *praehercynicus* appearance (see particularly Pl. 42, fig. 2, and Fig. 1b). Such were the first few complete '*praehercynicus*' rhabdosomes of *M. thomasi* which I came across and which misled me almost to the conviction that they might be true *praehercynicus*. Even simple effects of burial may obscure differences.

For a detailed and richly illustrated description of *M. praehercynicus* the reader is referred to Jaeger (1959). Only one notable amendment to the morphology of this species can now be added to that earlier discussion, namely data on the

course of the interthecal septa. This point had to be left open in the original descriptions, although I was inclined to believe that the condition observed in *M. uniformis* might also obtain for *M. praehercynicus*. However, a number of suitable rhabdosomes of *M. praehercynicus*, both from Thuringia and Bohemia, have shown me that *M. uniformis* and *M. praehercynicus* differ markedly from one another in this respect (see Fig. 1 j, g, 1).

In the proximal portion, say until th_{7-8} , the course of the interthecal septa still agrees in both forms; departing from an almost horizontal and accordingly very short septum in th_{1-2} , the succeeding septa become gradually more erect and longer, setting in progressively deeper, until in th_{7-8} the septum takes its origin in a level just touching or crossing the apertural hood of the preceding theca. While in *praehercynicus* this stage becomes the characteristic one, being retained from th_{7-8} until the very end of adult rhabdosomes, in *uniformis* the initial mode of progressive erection and prolongation of the interthecal septa continues for some distance. Therefore, distally from th_{7-8} the interthecal septa increasingly overlap, i.e. the thecae undergo a progressive imbrication. At th_{15-20} the beginning of the interthecal septum lies in the level of the hood of the second preceding theca. Further distally, the starting point of the interthecal septa in some rhabdosomes is still being somewhat advanced, however, not much below a level running through the ventral margin of the aperture of the second preceding theca. Consequently, a cross-section through a rhabdosome of *M. uniformis* will cut none or only one interthecal septum in the area between $th_{1-7(s)}$, one to two between $th_{7(s)-20}$ and two or even three beyond th_{20} , whereas in *M. praehercynicus* a cross-section will cut nowhere more than one interthecal septum, except in the apertural regions. Among the hundreds of rhabdosomes, collected at different levels in the *uniformis*-zone, and in which these features were studied, slight variations and irregularities have been observed. Thus, in the distal rhabdosome portion, the interthecal septa, even of adjacent thecae, may set in at levels slightly above or just touching the hood of the second preceding theca or crossing the thecal apertures at different heights.

Unfortunately, only a few certain *praehercynicus* rhabdosomes are available, in which the interthecal septa can be traced. Since, in 1959, I gave reasons for regarding *M. uniformis*-*M. praehercynicus*-*M. hercynicus* as forming an ascending lineage, transitions between both types of interthecal septa fabric would be expected. Indeed, rhabdosomes of *M. hercynicus* from the Serafshan Mountains (Tianshan, Central Asia), presented to me by Professor Obut (Novosibirsk), suggest that the contrast between the two types is only quantitative, but none in principle. In one available distal fragment of a *hercynicus* rhabdosome, of unknown but probably great length, the interthecal septa set in half-way between the preceding and second preceding theca (a degree of overlap, corresponding to the final *uniformis* type imbrication of thecae, believed to occur in *M. hercynicus* (Jaeger 1959, p. 89)), but since proved to be erroneous, an artefact of superposition. As can be observed in *hercynicus* specimens of known length, in the rhabdosome portion between th_{20-30} , the beginnings of the interthecal septa lie at a level crossing the apertural region of the preceding theca, while at the proximal end conditions are the same as in the proximal region of *uniformis* and *praehercynicus*. Hence, a progressive, though not necessarily steady, delay in the formation of the imbrication type of theca may have taken place during the phylogeny of the *uniformis*-*praehercynicus*-*hercynicus* lineage and caused the observed considerable differences in structure.

As illustrated in Fig. 1, the imbrication structure of thecae, so typical of *M. uniformis*, seems to be an exception among the uncinatate *Monograptus* species, all others corresponding to the type exemplified by *M. praehercynicus*. In addition

to the sketched species can be mentioned *M. perneri*, *M. boučeki*, and the true *M. similis*—all from the Upper Budnianian ($e\beta_2$). (In *M. hemiodon* and *M. ramstalensis* from the German Upper Graptolitic Slates the intertheal septa have not yet been observed.) There is in this group only *M. angustidens* Přibyl, which also possesses the imbrication structure; that species requires further study; however, many rhabdosomes originally referred to *angustidens* are in my opinion true *M. uniformis*, whereas others are distinct, but might at least in part be regarded as a small sub-species of *uniformis*. The imbrication structure of thecae is well known, of course, from a number of species belonging to other *Monograptus* groups, e.g. *M. roemeri*, *M. leptotheca*.

M. thomasi also compares closely with *M. hercynicus* in the general habit and size of the rhabdosome, and in the character of the thecae, including the decrease of the hoods in the median and distal parts of the rhabdosome; but the two are separated by the character of the proximal end, particularly by the peculiar shape of the sicula in *hercynicus* (Fig. 1 k, m). In cleaved rocks these features may be largely effaced. It may be noted that the *hercynicus* rhabdosomes from Central Asia and Nevada are considerably wider than the European and North African specimens, attaining the width of *M. uniformis*. It could perhaps be regarded as a geographical subspecies, even more, and is above all sharply distinguished by the imbrication structure of its median and distal thecae (see discussion under the heading *M. praehercynicus*). It must be stressed again, however, that the intertheal septa are indistinguishable in many specimens.

M. hemiodon Jaeger (not re-figured in this paper) from the basal part of the *hercynicus* zone in Germany, shows a slight tendency towards thinning of the proximal end, but attains a somewhat greater thickness than *M. thomasi* and, above all, lacks the hoods in the distal portion of the rhabdosome.

M. kayseri Perner (also not re-figured), occurring in the uppermost part of the *hercynicus* zone and perhaps even immediately above, is more or less concave throughout its length; it lacks also the stalk-like thinning in the proximal portion. (*M. belketaiefensis* Planchon (1964) founded on a few short (1 cm in length) and therefore possibly juvenile rhabdosomes, may be conspecific with *M. kayseri*, for in *M. kayseri* the characteristic dorsal concavity of the rhabdosome often becomes distinct only after the initial cm).

M. similis Přibyl (typical form) from the *ultimus* zone (basal $e\beta_2$) in Bohemia, a species which is still insufficiently known, approaches *M. thomasi* in the habit and size of the rhabdosome as well as in the distal diminution of the hoods, but differs markedly (1) in having the thecae more densely spaced (12-13 or more in the initial cm, against 9-10 in *M. thomasi*), in lacking (2) a dorsal reflexion of the proximal end and (3) a stalk-like thinning. There are other forms (Fig. 1h) belonging to this group, or which are at least of the same age as the typical *M. similis*; these have a comparable thecal count to *M. thomasi*, but are readily distinguished by being thinner and having unusually long hoods, the size of which remains constant throughout the rhabdosome.

M. uncinatus Tullberg from the Lower Ludlovian *nilssoni* zone (I cannot discriminate the variety *orbatus* Wood) with which *M. thomasi* has so often been compared, is separated chiefly by the following: (1) the hoods are of almost constant large size along the total rhabdosome length (this most significant difference was already noted by Harris & Thomas (1937, p. 74), and had led them to a reserved assignment of the Victorian specimens to *M. uncinatus*); (2) the thecae are set more closely (12-13 in the first cm, against 9-10 in *thomasi*); (3) there

is no tendency towards stalk-like thinning of the proximal rhabdosome portion and accompanying isolation of thecae.

M. micropoma from the Lower Ludlovian *nilsonni* and *scanicus* zones (mainly in the lower part) owing to the special development and structure of its hoods cannot be regarded as a mere variety or subspecies of *M. uncinatus*, but is a species of its own. It remains a bit weaker, somewhat thinner than *M. thomasi* (maximum width for flattened rhabdosomes 1.6-1.7 mm, and 1.2-1.3 mm excluding hoods), lacks the proximal stalk-like thinning and the isolation tendency of the early thecae and, above all, differs in the development and microstructure of the hoods. These are not homologous with the hoods of all the other uncinata *Monograptus* species discussed in this paper, they are not the distal extremities of the dorsal thecal walls (= interthecal septa), but are new independent elements formed in a late phase of the astogeny.

M. riccartonensis (Lower Wenlock) (not re-figured here), with which species of the *hercynicus* group are at present being confused all over the globe, differs distinctly in habit. The rhabdosome is long (reaching 10 cm or more) and slender, the proximal end is strongly recurved (affecting also the front of the initial 2-5 or more thecae); the hoods of at least the proximal thecae bear lateral spines.

OCURRENCE: Up to the present, *M. thomasi* n.sp. is only known from Victoria, where it is widespread. It occurs at many localities in central and east-central Victoria, arranged in the shape of an inverted 'L', and running from Scymour via the Yea-Molesworth district through the belts of graptolitic slates flanking the Walhalla synclinorium in the west, from the Eildon dam southward to the lower course of the Thomson R., i.e. extending over a distance of about 150 kilometres. Specimens from the following localities were available: Seymour, Marshalling Yards; Scymour East, Sanitary Gully; Alexandra, localities 5, 6, 9, and Killingworth, locality 13 of Harris & Thomas (1941, p. 302-304); Wilson's Creek Shale, Mt Sugarloaf, Eildon (Thomas 1947); 19 Mile Quarry (Yarra Track) (cf. paragraph 'type locality'); Thomson R. near Cole's hut, i.e. two miles below Jordan R. junction (cf. Baragwanath 1925, p. 21).

Stratigraphically, the occurrence of *M. thomasi* is confined to the Wilson's Creek Shale and its equivalents, which according to Talent (1965) is regarded as the eastern lateral equivalent of a substantial part of the coarser grained Mt Ida formation of the Heathcote district. *M. thomasi* characterizes the uppermost graptolite zone so far known in Australia. The species may range through 6,000 ft of strata in the Seymour district (N. W. Schleiger pers. comm.) and 1,500-2,000 ft at Eildon (D. E. Thomas pers. comm.), often abundantly covering individual bedding planes. It occurs to the exclusion of other graptolites, the only common associates being the plant *Baragwanathia*, and sometimes shelly fossils.

AGE: Since *M. thomasi* makes its appearance 1,500 ft above the horizon which yielded the basal Lochkovian ($e\gamma$) (= basal Gedinnian) *M. aequabilis*, and disappears 3,500 ft below the earliest small tentaculites (*Nowakia acuaria*, *N. intermedia*?), which from Central Europe to North Africa first appear in the *Monograptus hercynicus* zone, the *M. thomasi* horizon is tentatively correlated with some part of the middle Lochkovian ($e\gamma$), roughly corresponding to the *praehercynicus* zone. In terms of the Rhenish area the *M. thomasi* zone would cover a still undetermined portion of the interval between late Lower Gedinnian and Early Siegenian. This correlation agrees well with present evidence from shelly fossils, as demonstrated by Talent (1965). If this correlation of the *M. thomasi* zone is correct, *M. thomasi* would be a vicarious species of *M. praehercynicus*, suggesting provincial differences between the European/North African and Australian Early Devonian

graptolite faunas. However, a somewhat different approach appears to be also possible. Because of its stretched proximal portion, *M. thomasi* can be considered as further developed than *M. praehercynicus*, and therefore could well be younger. This suspicion is corroborated by its provenance. Despite its frequent occurrence through an enormous thickness of strata no other graptolite species have been found in association with it. This contrasts with the occurrence of *M. praehercynicus*, being usually associated with several other species. A possible explanation of this phenomenon could be that the *M. thomasi* zone occupies a still higher position in the graptolitic sequence than has been suggested in the preceding paragraph.

REPOSITORY: The bulk of the material from all mentioned localities, including the type-specimen, is housed with the Mines Dept of Victoria, Melbourne. A few samples are in the possession of some European museums, listed under 'acknowledgements'. Some further specimens are in the writer's collection.

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Explanation of Plates

All figured graptolites are more or less flattened and, in addition, are deformed by one system of transverse flow cleavages. The black or white stroke or arrow beside the figures indicates the direction of the tectonic stretching of the graptolites (= lineation = intersection of cleavage and bedding planes). All figures are unretouched.

Specimens from Eildon are not figured, as these have been well illustrated by Berry (1964a).

All numbers prefixed by 'M' refer to catalogue numbers in the Mines Department of Victoria, Geological Survey and Museum, Melbourne.

PLATE 41

Fig. 1-2—*Monograptus aequabilis* (Přibyl). (1) $\times 5$, (2) $\times 10$; (2) is counterpart of the proximal part of (1). The characteristic large hood of th_1 is well seen, especially in (2). Note the progressive diminution of the hoods in the succeeding thecae until they form only supra-apertural ridges. Obliqueness of the thecal apertures and free ventral walls is caused by cleavage. Note the interthecal septa and in (2) the long, forward bent dorsal tongue of the sicula. Locality: 20 Mile Quarry, Yarra Trak. Eildon Beds, Basal Loehkovian (ϵ_7) = Lower Gedinnian, zone of *Monograptus uniformis*. M 59523.

Fig. 3-5—*Monograptus thomasi* n.sp. (3 + 4) \times 5, enlarged rhabdosomes from the same bedding plane as illustrated on Pl. 42, fig. 7. Note: siculae; decreasing size of thecal hoods towards the distal end; more projecting hoods in the proximal thecae, especially in th₁; stronger projection of th₁ in fig. 3 increased by cleavage, but slightly decreased in rhabdosomes of fig. 4 (almost parallel to the lineation); stalk-like proximal rhabdosome portion—more pronounced by tectonical stretching in fig. 4, almost obscured in fig. 3. Locality: 19 Mile Quarry, Yarra Track, Wilson's Creek Shale, Lochkovian, zone of *M. thomasi*. M 58381. (5) \times 3, not so much flattened as the rhabdosomes from the 19 Mile Quarry locality; slight bending of the rhabdosomes caused by stronger cleavage; bedding planes somewhat wrinkled. Turn the picture! Alexandra, locality 6. M 32562.

PLATE 42

Fig. 1—*Monograptus praehercynicus* Jaeger. \times 3; cf. sicula and proximal rhabdosome portion with *M. thomasi*. Locality: Ramstal, Thuringia, Germany; *praehercynicus* zone. Mus. Pal. Berlin, g 30 d.

Fig. 2-7—*Monograptus thomasi*, n.sp. (2) \times 3, lying normal to lineation, note: proximal 'stalk' entirely obliterated owing to shortening. (3) \times 3, shows stalk-like proximal portion, not modified by cleavage. (4) \times 5, note progressive erection of interthecal septa towards the distal end. (5) \times 5, not so much flattened; note thecal hoods and aperture of the sicula. (6) \times 5, note interthecal septa in the distal rhabdosome portions; turn the picture! (7) \times 1, note width of rhabdosomes directly proportional to the angles, which they make with the lineation. (Reverse side of the slab containing the holotype). (2) + (4) 19 Mile Quarry, National Museum, Prague, Akc. kat. 37 766, R 1949, Inv. No. I, 47 (specimens lying on the same slab). (3) Alexandra, locality 9. M 32598. (5) Alexandra, locality 6. M 32554. (6) + (7), 19 Mile Quarry. M 58382 and M 58381 respectively.

PLATE 43

Monograptus thomasi n.sp. \times 5; rhabdosome signified by the arrow, which also indicates the direction of the lineation, is the holotype (slightly tilted during burial). 19 Mile Quarry, Yarra Track. Geological Survey of Victoria 58381.